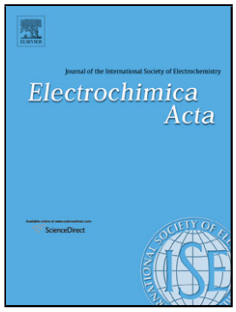

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Synthesis and Characterization of Solid Polymer Electrolyte based on Activated Carbon for Solid State Capacitor

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Abstract

This paper describes the synthesis and characterization of a new silver ion conducting solid polymer electrolyte based on activated carbon. Solid nanocomposite polymer electrolytes and their application in energy storage devices has been widely studied because of their environmental safe, no leakage and ion transport mechanism directly connected with the salt (silver iodide) used. Aqueous and non-aqueous electrolytes are widely used in electronic devices but have numerous limitations such as volatility, flammability and leakage. Therefore, we have developed all solid state capacitor in this report and used polymer electrodes and electrolyte as the host. A solid polymer electrode of type 1 – x (70 polyethylene oxide: 30 silver iodide): x activated carbon (where $x = 10 \leq x \leq 50$ wt.%) composites have been synthesized using hot press method. The ionic conductivity has been significantly improved for the optimum amount (30 wt.%) of the activated carbon added into the polymer host. The performance of the synthesized electrodes is studied by various physical and electrochemical methods. The leakage current and self-discharge characteristics of the solid state capacitor device have been reported.

Keywords: Solid polymer electrolyte; PEO; Activated carbon, Conductivity; Capacitor

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1. Introduction

Electrolytes can be generally divided into three sections, and they are classified as liquid, solid and composite. These three electrolytes have their own merits and de-merits. Liquid electrolytes are again divided into aqueous and non-aqueous. The advantages of using liquid electrolytes are that they possess high conductivity and better contacts with the electrodes [1], however, some are flammable and cause spillage in the case of device breakage or thermal runway [2]. On the other hand, in the composite electrolyte, plasticisers such as ethylene carbonate, propylene carbonate are commonly added into host polymer matrix to produce plasticized polymer electrolytes [3-4]. The advantages of using composite electrolyte are there is no leakage but their ionic conductivity is achieved at the expense of their mechanical strength [5-7]. Also, using organic solvents and ionic liquids are not environmentally friendly and thermally stable. In contrast, the solid polymer electrolytes (SPEs) are emerging as a new class of technologically important materials suitable for energy storage devices [8-9]. SPE is synthesized by dissolving the salt of alkali metals of type MX (M = Na, Li, Ag, Cu, etc. and X= F, Cl, I etc.) in polymer i.e. polyethylene oxide, polypropylene oxide etc [10-11]. In the polymer host, addition of small wt. % (weight percent) of inorganic fillers such as Al_2O_3 and SiO_2 enhances the conductivity of the polymer electrolyte [12-13]. The increase in conductivity through the addition of the fillers inhibit the recrystallization of the polymer and decrease the glass transition temperature of the SPE and hence the conductivity [14]. Several studies had been demonstrated on the influence of the range of inorganic fillers and its effect on conductivity [12-15]. In continuation to this, in one of our earlier reports, we have detailed the role of Al_2O_3 as inorganic filler and its influence on ionic conductivity [16]. Based on this study, we have optimised the electrolyte composition 93(70PEO:30AgI): $7Al_2O_3$ (PEO denotes polyethylene oxide) that exhibiting excellent conductivity, ion transport number and

activation energy a pre-requisite for solid state electrochemical devices. This electrolyte is used in the current work for solid state capacitor applications.

Capacitors are one of the emerging energy storage devices, however lower ionic conductivity of the solid polymer electrolyte [2] and the poor accessibility of the ions in the active sites in the device, limit their wide application in the electronics industry. Hence, the focus of the current study is to synthesize a novel electrode incorporating high surface area of activated carbon (AC) and to evaluate its suitable proposition in the host polymer matrix (70PEO:30 AgI). The presence of activated carbon not only improves the conductivity of the matrix but also solving the transportation of ions into the active sites. The new conceptual idea of using activated carbon is due to its high surface area and amorphous in nature. An increase in amorphosity of the polymer matrix may result in higher ionic conductivity because it is widely agreed that the ionic conduction in the amorphous phase is much greater than that of the crystalline part [17-18].

To this end, a solid polymer electrode based on 1–x (70PEO:30AgI): x AC (where x = $10 \leq x \leq 50$ wt. %; AC denotes activated carbon) composites, hereinafter referred as PAC, have been synthesized successfully. A hot press technique was used for the synthesis of PAC electrodes. The hot press technique is currently being preferred over the usual solution cast technique [19]. The current work is also framed to explore the knowledge of the physical and electrochemical properties of the synthesized PAC based electrodes. The thermal stability and morphological studies of PAC electrodes were investigated via thermo gravimetric (TG) and scanning electron microscopy (SEM) analyses. The electrochemical double layer reactions on the electrode were characterised using electrochemical techniques such as impedance and cyclic voltammetric studies. The PAC electrode having the composition 70(70PEO:30AgI):30AC is referred as optimum conducting composition and denoted as "PAC (OCC)". Finally, a solid state capacitor has been fabricated "PAC (OCC)

|93(70PEO:30AgI):7Al_2O_3| PAC (OCC)" and its capacitive behaviour is reported in this study. The capacitor based on the PAC (OCC) electrodes in solid polymer electrolyte showed a signature of capacitance behaviour but only with lower capacitance equivalent to 5 F/g for a device.

2. Experimental

Poly ethylene oxide (PEO; Mw of 10^5, Aldrich, USA) based conducting electrode 1 – x (70PEO:30AgI): x AC (where x = 10 ≤ x ≤ 50 wt%; AC denotes activated carbon) were prepared by using a hot press method in place of the conventional solution-cast technique. Hot press treatment was carried out at 100° C and after this the surface of the polymer becomes very smooth and transparent. The details and advantages related to hot pressing technique have been given elsewhere [20]. The precursors AgI (98%) and AC (99%) were purchased from Redial laboratory reagent and Loba Chemie Pvt. Ltd, respectively. The surface area of the AC powder is 1400 m^2/g and the pore volume is calculated to be 0.45 cm^3/g. The earlier reported standard electrolyte (70PEO:30AgI) [16] was used as the base material. Required amount of dry precursor (AC) in appropriate wt. is added to the standard electrolyte material and the ingredients were thoroughly ground at room temperature for about 10 min using an agate mortar and pestle. The physically mixed salt mixtures of different compositions were then heated close to the melting point (about 100 degree C) in a muffle furnace for about 20 minutes to evaporate moisture. This resulted in soft slurry of polymer encapsulated with the AgI salt and activated carbon. The obtained slurry was then pressed between blocks of two stainless steel (SS) by applying a pressure of ~2 tons/cm^2. This was resulted in thin polymer layer of area ~1.85 cm^2 having uniform thicknesses of 0.14, 0.125, 0.0622, 0.1 and 0.129 cm corresponding to respective wt. % contents of activated carbon (AC) 10, 20, 30, 40, 50 of AC in PAC electrodes. All solid-state symmetric

capacitor has been constructed using the synthesized PAC electrodes on both sides as "symmetric device" and the nanocomposite polymer electrolyte with the composition 93(70PEO:30AgI):7Al_2O_3 is sandwiched in between these electrodes. Egg shell membrane was used as the separator. The role of the separator is to provide minimal resistance for electrolyte ion's movement and to avoid any electrical contacts between the polymer electrolytes. The schematic diagram of solid state capacitor device representing the cell components is shown in Fig. 1. The PAC electrodes have been synthesized and studied for its suitability in solid state devices.

The electrochemical impedance spectroscopy measurements were carried using the instrument Princeton Applied Research (Versa Stat III model) at a frequency range of 1 MHz to 10 MHz. The applied potential amplitude of the signal was varied from 5 mV. Thermo gravimetric analysis (TGA) for the PAC electrode was conducted using TA instruments (SDT 2960). The surface analysis of the materials was conducted using a scanning electron microscope (Philips Analytical XL series 20). The capacitor measurement was carried out in a potentiodynamic and galvanostatic modes between the voltage limits of 0 and 1.0 V at a sweep rate of 1 mV/s and constant charge-discharge current of 0.1 mA (0.05 A/g) respectively.

3. Results and Discussion

A Cole-Cole plot [21], plot of Z'' on the y (or imaginary) axis vs. Z' on the x (or real) axis is shown in Figure 2. Electrochemical impedance spectroscopy (EIS) technique is commonly used in analysis of electrolytes where ionic conduction strongly predominates [22]. The PAC electrode is a suitable material to examine via EIS where conduction involves motion of ion vacancies and interstitials. Figure 2 shows Cole-Cole plots for PAC electrode (1-x (70PEO:30AgI): x AC; x = 10 ≤ x ≤ 30 wt.%) having different contents of activated carbon

(AC). The inset shows the plot for lower contents of AC such as 10 wt.% and 20 wt.%. The 10 wt.% AC consist of larger semicircle, in which high frequency attributed to bulk conductivity and the low frequency portion ascribed to the interfacial impedance [23]. The large semicircle should comprise a charge transfer resistance (interfacial resistance, Rct) and a constant phase element (CPE) models the behavior of a double layer in non-ideal capacitor [23]. The radius of the semicircle decreases with a depressed origin with the increase in AC content (20 wt.%), indicating an increase in the mobile charge carriers influenced by the highly conducting and larger surface area of carbon. For 30 wt.% AC, with a depressed semi arc, the plot in Fig. 2 is parallel to the imaginary axis with an intercept on real axis at very close to origin implying an ideal capacitor like behaviour. The plots for the higher contents of AC such as 40 % and 50 wt.% consist of high-frequency semicircular arc assigned to ion conduction, followed by a low-frequency line arising from the electrode polarization (Rf). The intercept of the semicircle with the real axis (Z') gives an estimate value of the Rs of the samples that be used for evaluation of ionic conductivity, discussed in the subsequent section. The ionic conductivity of the samples were calculated using the relation $\sigma = (1/R_s \times t/A)$, where A is area of the electrolyte film and t is the thickness of the film.

The equivalent circuits used for the fitting of EIS data are shown in Fig. 3. The different components used in this circuit have the physical meaning [24-25] which are as follows: Rs the electrolyte resistance of the cell, Rct the interfacial charge transfer resistance, Cdl the double layer capacitance, W the Warburg impedance, CPE the constant phase element, Rf the polarization resistance, C1 the intercalation capacitance. A typical characteristic of the impedance plot for the lower content of AC can be fitted by an equivalent circuit shown in the Fig. 3a. The diameter of the semicircle corresponds to the interfacial charge transfer resistance (*R*ct), which usually represents the resistance of the electrochemical reactions at the electrode surface and the Warburg impendence (W) ascribed

to the diffusion resistance of the ion transfer in the host polymer electrode [23, 26]. At high frequencies, Warburg impedance (W) is negligible (0.050 – 0.075 Ω cm^2 $s^{-1/2}$) [26] indicating the diffusion behavior has not been observed for 10 and 20 wt.% AC. The *R*ct resistance values extracted from the impedance plot are 6.2 x 10^4 Ω cm^2, 1.0 x 10^4 Ω cm^2, for the 10 and 20 wt.%, respectively, which reflects that the 20 wt.% achieve the better conductivity. The high frequency region is generally contributed by the ionic conduction through the polymer electrode and it behaves like an ideal resistive behavior as the Z" is close to zero. In electrochemical systems, capacitance is typically modelled as a constant phase element (CPE) that describes non-ideal capacitive behavior [25]. In the case of lower contents of AC (10 and 20 wt. %), CPE fitting values of 0.2 and 0.8 mF cm^{-2} were used for impedance spectra. In the case of higher contents of AC (30 wt.% – 50 wt.%), the most vertical line in the low-frequency region of the 30 wt.% indicates that this material possesses the best access path of electrolyte ions to the host PAC electrodes. The impedance plot for the higher AC consists of a high-frequency depressed semicircular arc, attributed to ion conduction and is followed by an inclined line in the low-frequency region a result of ion transport through the pores of the PAC electrodes. The experimental impedance spectra for the higher contents of AC were fitted with an equivalent circuit model shown in Fig. 3b. To include the intercalation activity and the resultant polarization of the cell resistance, the corresponding components (C1 and Rf) are added in the circuit and the fitting parameters are tabulated in Table 1.

The results obtained from Cole-Cole plot and the fitting parameters conclude 30 wt.% AC depicts an isometric plot, approximating a vertical line with a slope of quasi 90° to the Z' axis indicating the excellent double layer capacitance of electrode/electrolyte interface of the polymer electrode for capacitor applications.

Figure 4 shows the plot of ionic conductivity dependence of the PAC electrode with different weight content of AC at ambient temperature. The ionic conductivity of the PAC

electrode increase with AC content, to the optimum level then it start to fluctuate with the addition of AC loading beyond 30 wt.%. The ionic conductivity increases by the increase of AC may be due to mobility of charge carrier is increased [27] while assuming (from the evidence of SEM microstructure detailed in the next section) that AgI is uniformly distributed. It is shown in the plot (Fig. 4) that ionic conductivity of PAC electrode has reached the highest value of $\sigma = 1.92 \times 10^{-3}$ S/cm) with 30 wt.% AC having the composition 70(70PEO:30AgI):30 AC referred as optimum conducting composition denoted as PAC (OCC). The higher concentration of AC (> 30 wt.%) does not increase the conductivity rather it started fluctuating, implying activated carbon led the polymer electrolyte to suppress the polymer chain motion and thus inhibiting the transport of Ag ions [28]. It is generally accepted that the conductivity of crystalline PEO electrolytes is much lower than that of the amorphous counterparts, as the conduction channels are blocked and the segmental mobility of the backbone is minimum [29]. This could be attributed to the variation of the ionic conductivity seen over the optimum content of 30 wt.%. The results on conductivity measurements are in good agreement with the electrochemical results i.e. impedance spectra verifying that the higher contents of AC (≥ 30 wt. %) showed a performance superior to their lower counterparts of 10 and 20 wt.% AC.

Thermal gravimetric analysis (TGA) was carried out to determine the thermal stability of the PAC (OCC) electrode for its capacitor application. To study the effect of carbon concentration, thermal behavior of the PAC (OCC) electrode was compared with higher contents of AC and their results are superimposed in figure 5. TGA curves show the loss in weight of the electrodes measured as a function of temperature and implies the thermal stability of the electrode over a wide temperature region. PAC (OCC) electrode (Fig. 5a) exhibited an initial weight loss of 5% at the region of 200^{o} C, which is very negligible, may be due to the presence of some carbonaceous products. This illustrates prepared PAC (OCC)

electrodes remained stable up to 200^{o} C. Above this temperature, thermal decomposition of the electrode was observed with a weight loss of 25% at around 300^{o} C. The polymer electrode lost approximately 30% of the weight at temperatures up to 400^{o} C. A third weight loss of another 20% (total weight loss of 50%) was observed only after 400^{o} C which is attributed to polymer degradation. The shape of the thermal curves appear to be invariant with different carbon ratios studied but a maximum weight loss was noticed (Fig. 5 b-c) only for the higher carbon ratios illustrating the suitable composition for PAC electrode could be 30 wt.%. In summary, the TGA of the PAC (OCC) studied was found to be thermally stable over a wider temperature as compared to the standard electrolyte (70PEO:30AgI) reported earlier [16, 30-31].

The surface morphology of the PAC (OCC) electrodes was characterised by scanning electron microscopy (SEM). The SEM images of the electrodes under different magnifications are shown in Fig. 6. The obtained morphology was found to have rough surface (Fig. 6a) but uniform distribution of microstructure is observed without major cracks. This illustrates activated carbon was homogenously dispersed on the host PEO polymer electrolyte. To have more information on the electrode, the same area has been magnified 5x and its micrograph is seen in Fig. 6b. This is in contrast to the lower magnification. Rod shaped morphology could be of porous activated carbon and a shiny tiny material could be related to AgI. High porosity nature of AC provides a larger surface area on which the base PEO: AgI electrolyte clings on it. This helps the Ag ions to be actively distributed on the electrode surface. The corresponding energy dispersive spectra (EDS) of the carbon-rich area is shown in Fig. 6c, evidencing the presence of C, Ag and I. The lighter elements C and O are shown at the lower energy levels while Ag and I are at around 3 keV. It clearly shows that the concentration of C appears to be high in the sampled area and in addition to that the presence of carbon is always associated with Ag and I in the area of analysis. This confirms the

activated carbon in the electrode enhances the distribution of Ag ion homogeneously. However, in order to understand the role of increasing carbon content with the distribution of Ag ions, the SEM micrograph of PAC (OCC) electrode was compared with higher contents of AC. As seen from the micrographs (Fig. 7), under the identical SEM settings (accelerating voltage 20 KV; magnification 2.25 K; with the same spot size), carbon particles aggregates (Figs. 7b-c) for the higher carbon contents with Ag ions (shiny tiny material) scarcely located. The presence of higher amount of activated carbon may increase the surface area but inhibits the transportation of base (PEO: AgI) electrolyte within the host network. Hence, the higher composition of AC in the host polymer matrix may not be feasible for supercapacitor application due to lack of ionic transportation through the bulk of active electrode. The microstructure of the 30 wt. % sample confirmed that the chosen wt. % of the electrode PAC (OCC) is compact with Ag ions and porous therefore found to be suitable for capacitor applications.

The use of PAC (OCC) electrode in capacitors is expected to give high conductivity and hence these electrodes are placed on both sides as "symmetric device" and the nanocomposite polymer electrolyte 93(70PEO:30AgI):7Al_2O_3 is sandwiched in between these electrodes. A potentiodynamic technique, cyclic voltammetry, is carried out to study the capacitive behaviour of the constructed cell (schematic diagram of the cell is shown in Fig.1). In cyclic voltammetry, potential is varied linearly between an initial and final potential (0.1 and 0.9 V) at a sweep rate of 1 mV/s and change in the current (i) is recorded and substituted in Eq. (1). The current (in terms of capacitance) – potential curve of a PAC (OCC) | 93(70PEO:30AgI):7Al_2O_3 | PAC (OCC) is shown in Fig. 8. As the potential is swept anodically, the electrode oxidises near the surface that generates a current response. Reversal of the sweep cathodically, reduces the same electrode and another set of current response is measured. One such typical cyclic voltammogram is shown in Fig. 8 mimicking a double

layer capacitance associated with the electrode/electrolyte interface [32-33]. An all solid-state capacitor using polymer electrolyte mimics to have a capacitance behavior (in Fig. 8) with storage capacity of approx. 5 F/g which is comparable to that of reported value for all solid state capacitor [34–36]. However, this capacitance need to be substantially improved for any practical applications and further work is underway.

The specific capacitance (F/g) of the PAC (OCC) electrode is calculated by integrating the area under the cyclic voltammogram (Fig. 8a) using the following equation [1]

$$C_s = 2 * \frac{1}{vm(E_1 - E_2)} \int_{E1}^{E2} i(E)dE \qquad \text{Eq. [1]}$$

Where E_1–E_2 is the applied potential window (1 V), m is the mass of the total material in one of the electrodes (2 mg) and *v* the scan rate (1 mV/s). The specific capacitance (F/g) of the PAC (OCC) electrode is also calculated from the galvanostatic charge-discharge curves (Fig. 8b), using the following equation [2]:

$$C = 2 * \left(\frac{i\,\Delta t}{\Delta v \times m}\right) \qquad \text{Eq. [2]}$$

where *i* denotes the constant current used for charging and discharging (0.1 mA; 0.05 A/g), *m* is the mass of the total material in one of the electrodes (2 mg), Δt is the charge/discharge time and Δ*v* being the potential window (1 V). As the electrochemical experiments have been carried out in a symmetrical two electrode configuration (as shown in Fig. 1), the obtained capacitance values (2.5 F/g) of the cell will be half of the single electrode, hence it is multiplied by the factor of 2 (as included in the above two equations (1-2) achieving 5 F/g. For an ideal capacitor, the cyclic voltammetry curve represents a rectangular shape [33] but the representation of typical voltammogram observed in Fig. 8a may be due to resistive nature of host polymer matrix itself. However, a typical symmetric charge-discharge profile

without any distortion (Fig. 8b) exhibited excellent electrochemical behaviour for continuous cycling (20 cycles) indicating the stability of the PAC (OCC) electrode. The voltage loss (ohmic drop) after a full charge (Fig. 8b) is a measure of evaluating the equivalent series resistance (ESR) of the supercapacitor device [37]. The observed low ohmic drop (ΔV = 0.053) support the excellent capacitive properties of the PAC (OCC) electrode. The observed mimicking capacitive behaviour could be attributed to the high surface area of activated carbon where the adsorption/desorption of Ag ions can take place.

In a practical application, the dielectric between the symmetric electrodes of the capacitor allow a small amount of current to leak which will cause the potential decay of a charge state of the capacitor over time [38]. Along with leakage current, another important factor is self-discharge to evaluate its performance [39]. Ideal capacitors maintain constant potential without any flow of current from an external circuit. While real capacitors, require a current, called leakage current to maintain constant potential. We measured the leakage current of the device by charging at 1.8 V and by monitoring the current required to maintain that specific potential. In our symmetric device, as shown in Fig. 9, the leakage current dropped significantly when the potential is applied initially (from 50 μA to 20 μA after 200 min) and then gradually the loss in current was smaller and kept stabilising (finally to only 5μA after 25 h). This value is less compared with those for reported in the literature [36 - 38] and it's a characteristic of electrochemical double layer formation. The open-circuit (self-discharge) potential of the device decreases the energy accumulated by the capacitor and the change in potential profile is shown in Fig. 10. The potential decreases from its initial value of 2 V to 1 V relatively in a rapid manner and then slows down with time. The practical advantage of low self-discharge course is very attractive for its use in standby power etc. On the basis of physical and electrochemical studies, it can be confirmed that the newly synthesised polymer based electrodes (PAC OCC) through hot press technique performed

relatively well and the presence of activated carbon enhanced the ionic conductivity and Ag ion diffusion mimicking as capacitor behavior. Nevertheless, extensive work is required to enhance the performance of the capacitance in the solid state capacitor.

4. Conclusions

A solid polymer electrode based 1 – x (70PEO:30AgI): x AC (where x = 10 ≤ x ≤ 50 wt%; AC denotes activated carbon) composites have been synthesized successfully by hot press method. The incorporation of activated carbon in the host electrolyte has led to significantly enhance the ionic conductivities. From the impedance plots, the reduced charge-transfer resistance with a slope vertical to Z' axis obtained for 30 wt.% AC suggested that this composition has an excellent capacitive behavior. Likewise, among the weight percent of the AC content studied, 30 wt.% exhibits the highest conductivity of 1.92×10^{-3} S/cm. Hence, 70(70PEO:30AgI): 30 AC (PAC) has been chosen as the optimum conducting composition denoted as PAC (OCC). The chosen composition was widely characterized using various techniques like TGA, SEM and other electrochemical methods like impedance spectroscopy and cyclic voltammetry. A solid state symmetric capacitor PAC (OCC) | (70PEO:30AgI):7Al_2O_3 | PAC (OCC) has been assembled and its capacitor behaviour including important factors like leakage current and self-discharge characteristics were studied. Further extensive investigations may be required to improve the storage capacity of the fabricated solid state capacitor for any practical applications. To conclude, the present work puts forward a novel and cost effective polymer electrodes that are suitable for all solid state capacitor using an adsorption-desorption & intercalation mechanisms in the polymer encapsulated AgI and activated carbon.

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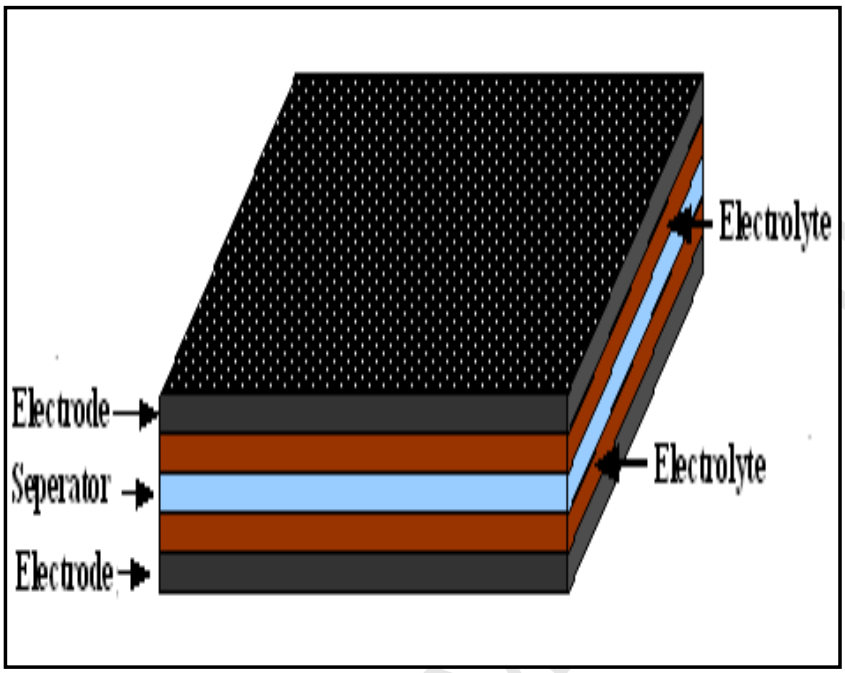


Figure 1 Schematic diagram of the all Solid State Capacitor with the configuration **(Electrode)** 70 (70PEO:30AgI): 30 AC | **(Electrolyte)** 93(70PEO:30AgI):7Al_2O_3– **Separator** – **(Electrolyte)** 93(70PEO:30AgI):7Al_2O_3 | **(Electrode)** 70 (70PEO:30AgI): 30 AC

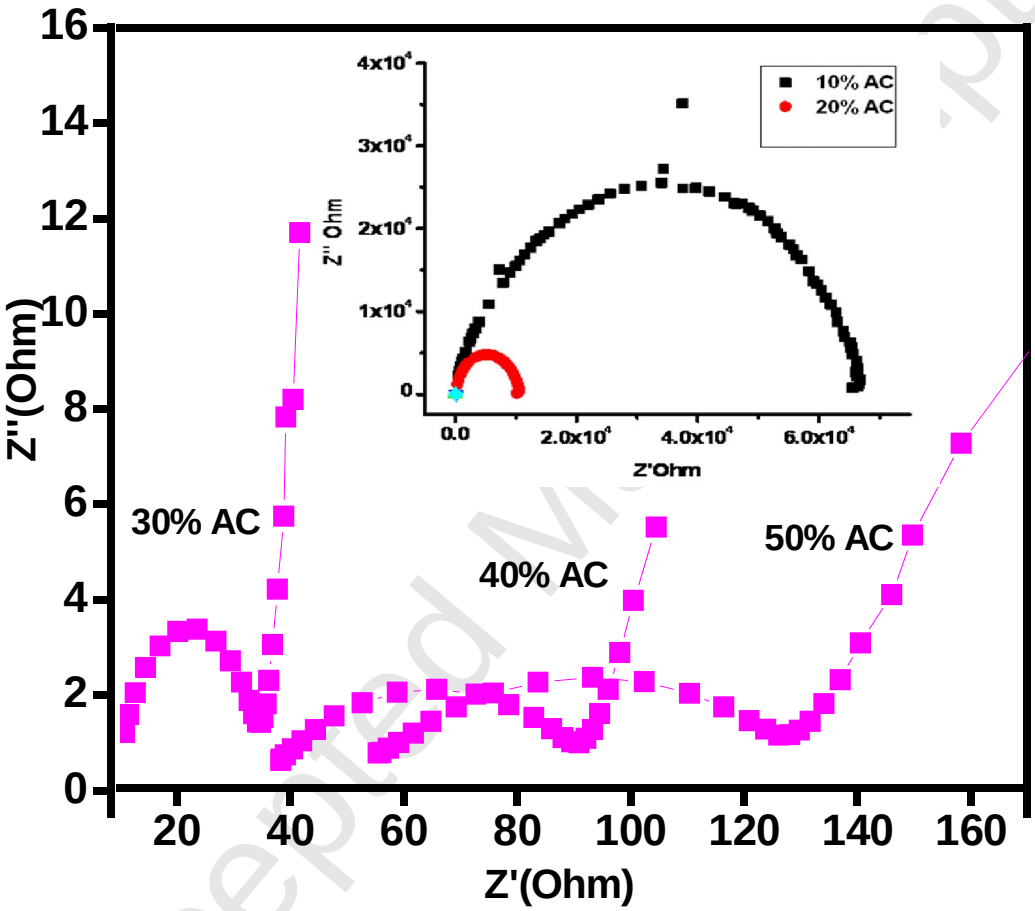


Figure 2 Cole-Cole plots of 1-x (70PEO:30AgI): x AC (where x = 10 ≤ x ≤ 50 wt%; AC denotes activated carbon) polymer electrode as a single electrode.

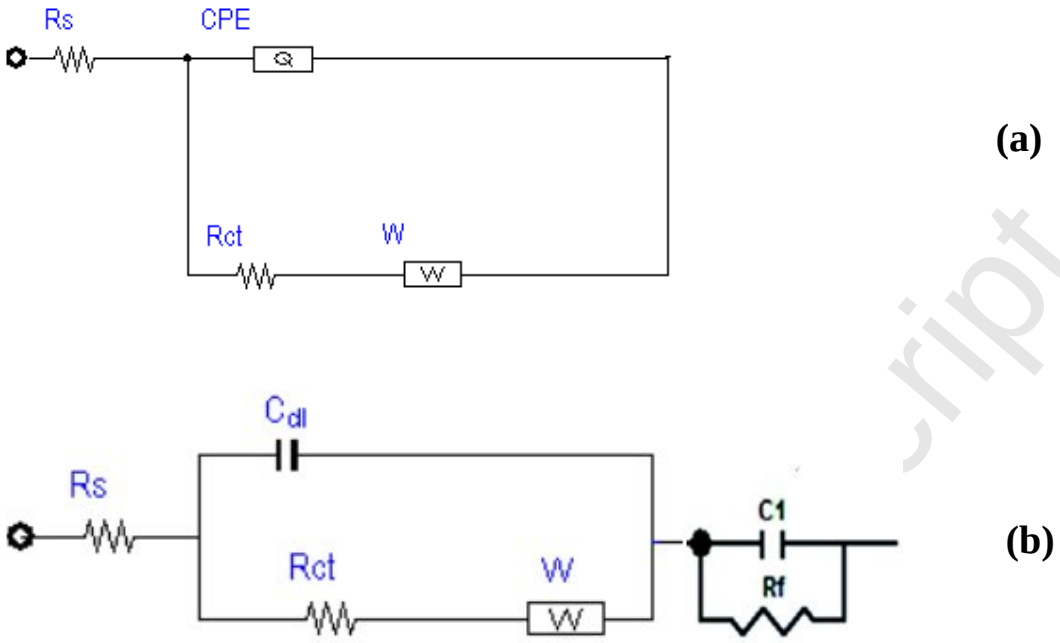


Figure 3 Schematic diagram of the corresponding equivalent circuit to the impedance plot shown in Fig. 2 with the (a) lower (10 – 20 wt.%) and (b) higher contents (30 – 50 wt.%) of activated carbon (AC).

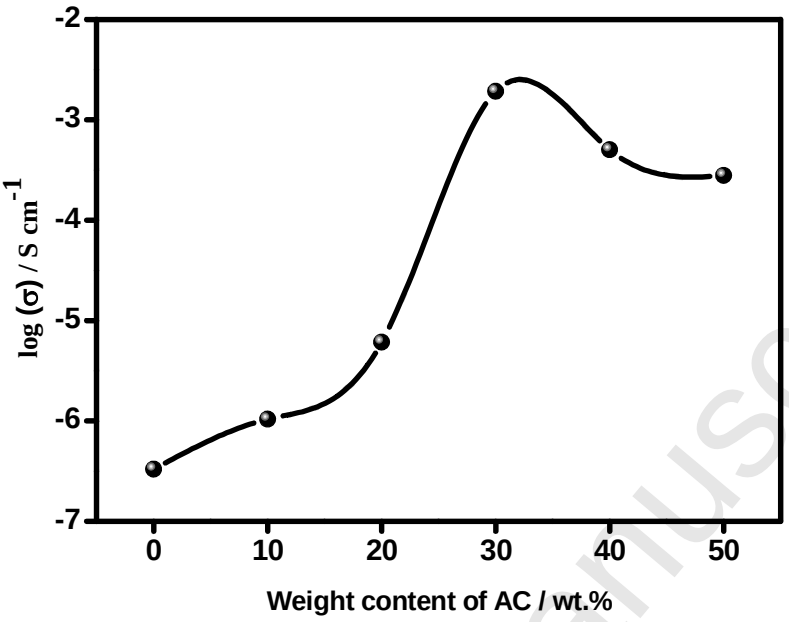


Figure 4 Ionic conductivity of the electrolyte 70(70PEO:30AgI):30AC (denoted as PAC (OCC)) with different compositions of active carbon.

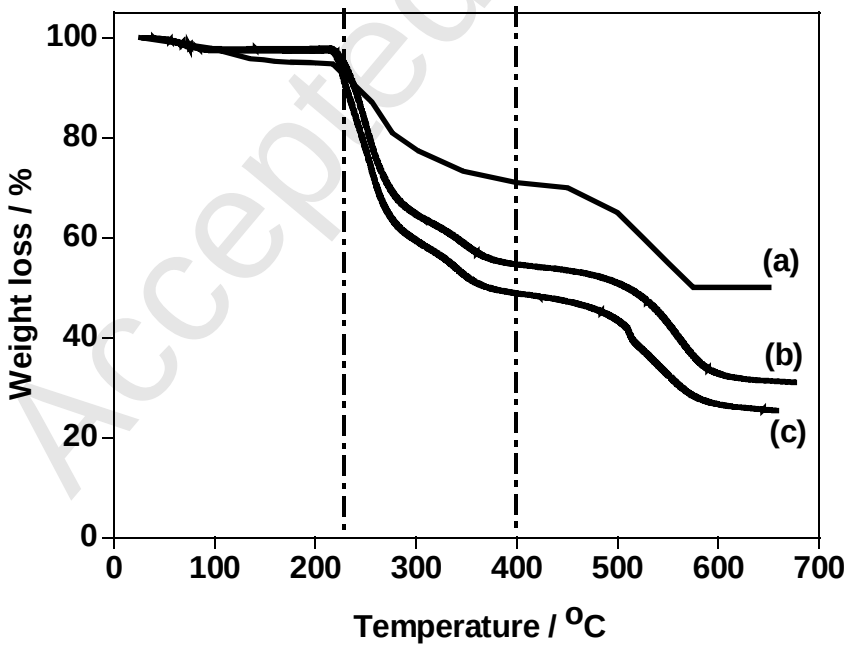


Figure 5 Thermo gravimetric analyses (TGA) of the (a) PAC (OCC) polymer electrode (30 wt.%) compared with higher contents (b) 40 wt.% and (c) 50 wt.% of activated carbon (AC).

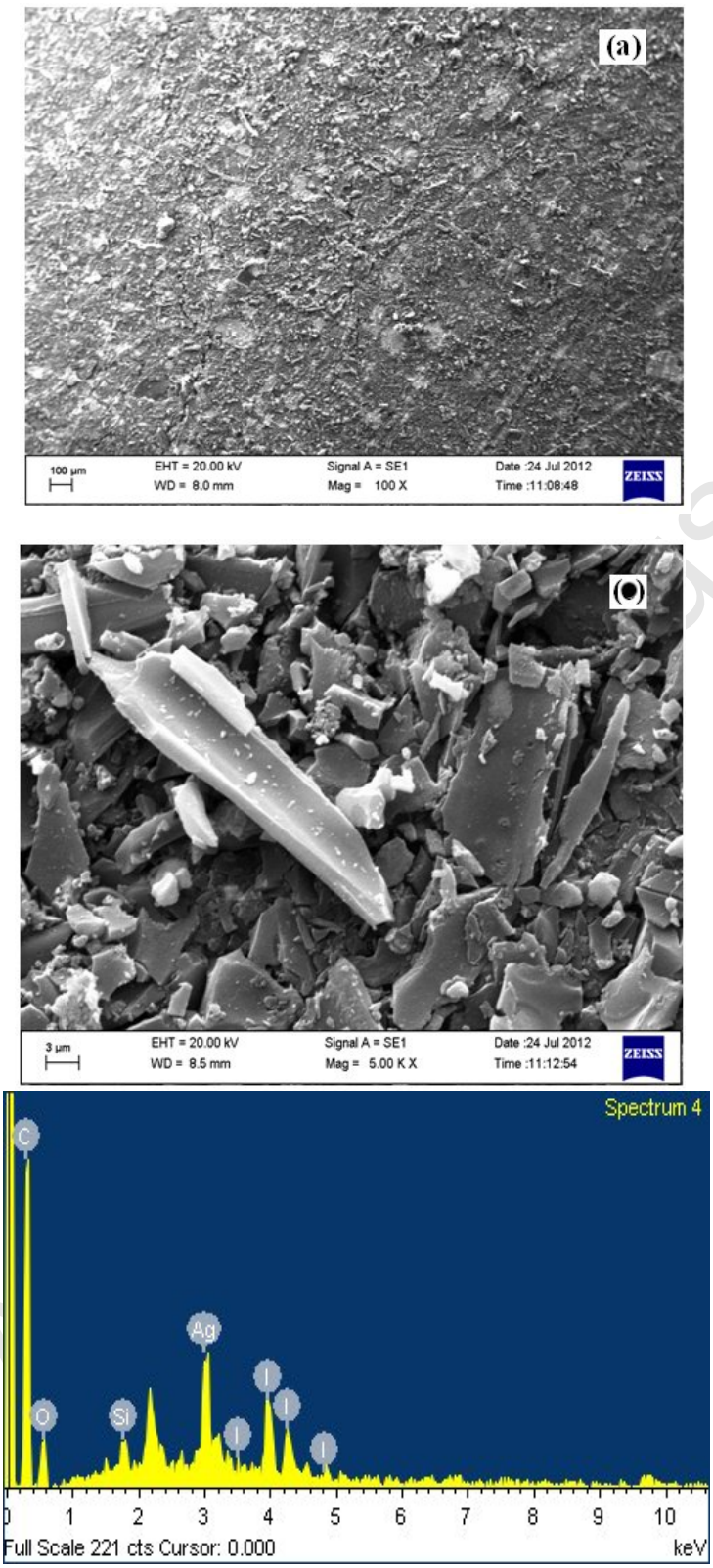
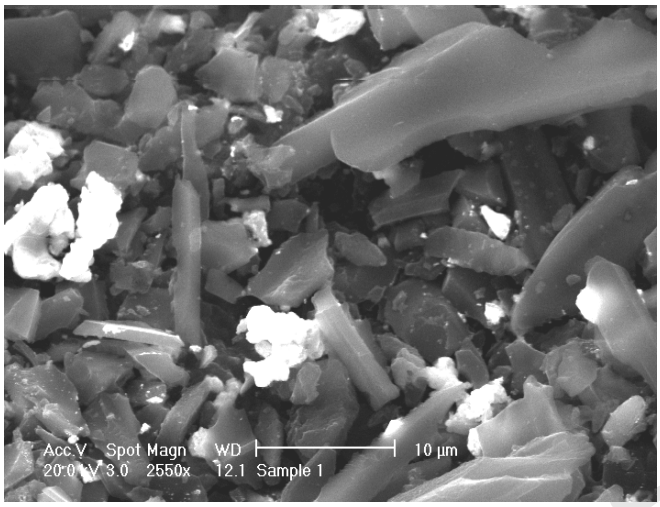
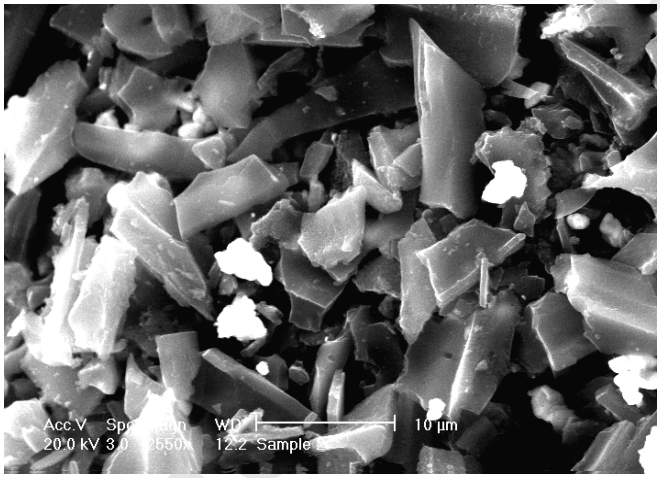


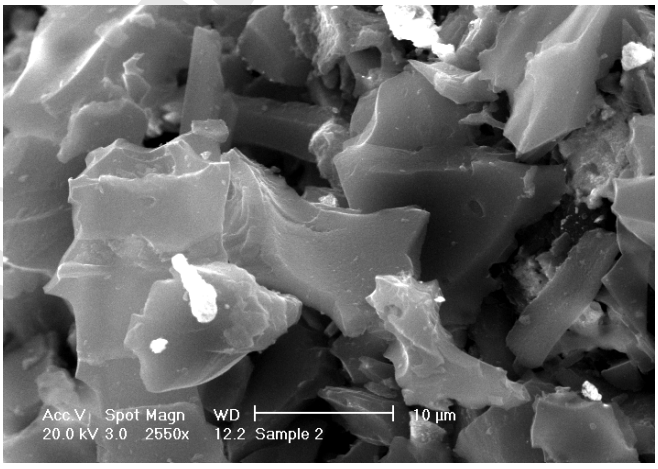
Figure 6 (a-b) Scanning electron micrographs of PAC (OCC) polymer electrodes under different magnification. Fig. 4c. Energy dispersive analysis showing elemental concentration taken in the area of Fig. 6b.



(a)



(b)



(c)

Figure 7 Scanning electron micrographs of (a) PAC (OCC) polymer electrode (30 wt. %) compared with higher contents (b) 40 wt. % and (c) 50 wt. % of activated carbon (AC) under identical magnification.

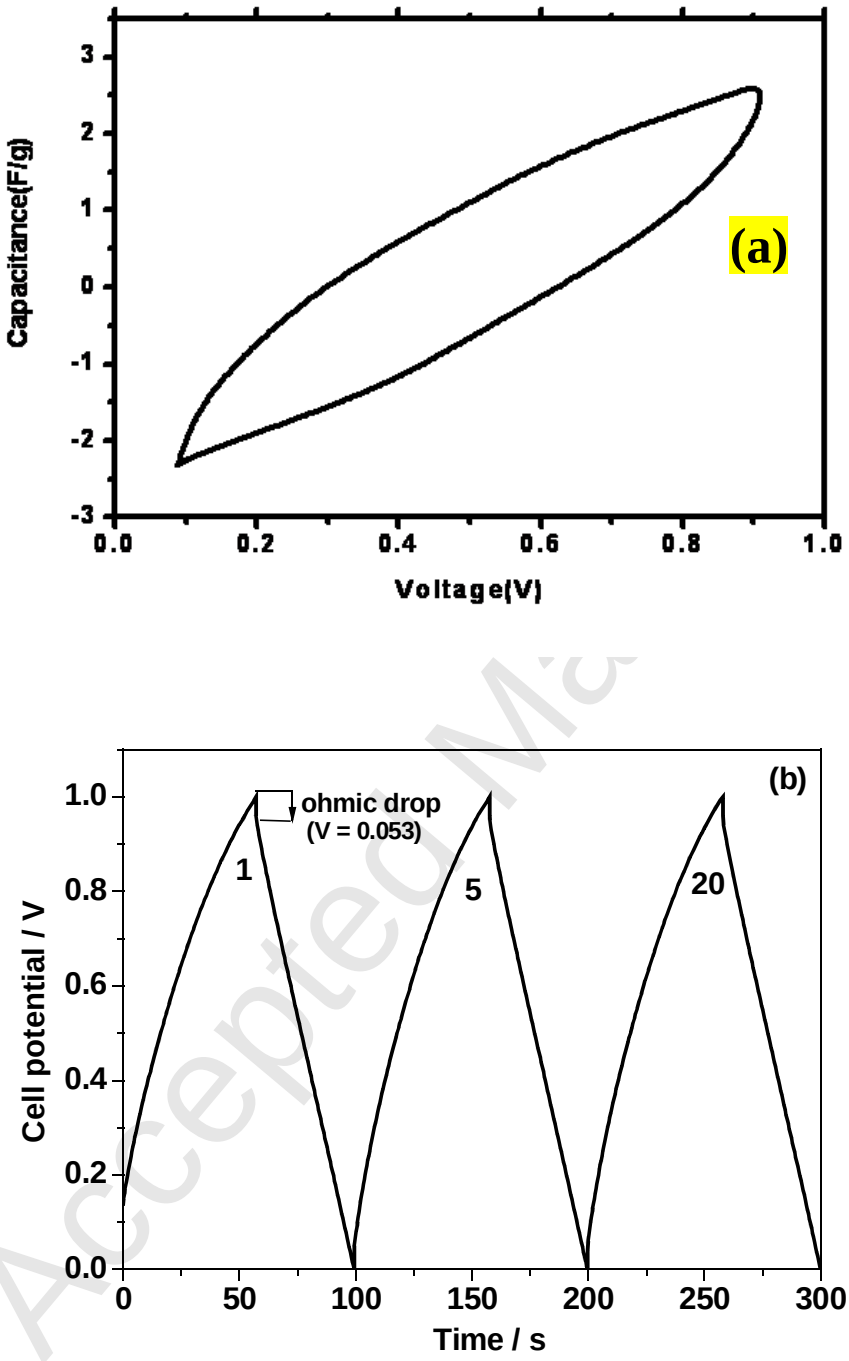


Figure 8 All solid state capacitor device comprising PAC (OCC) polymer electrodes showing EDLC like mechanism analysed through (a) potentiodynamic and (b) galvanostatic techniques. The solid polymer electrolyte is sandwiched between the two electrodes and the device is represented as PAC │93(PEO:30AgI):7Al_2O_3│PAC. Cycle numbers are indicated in the figure 8b.

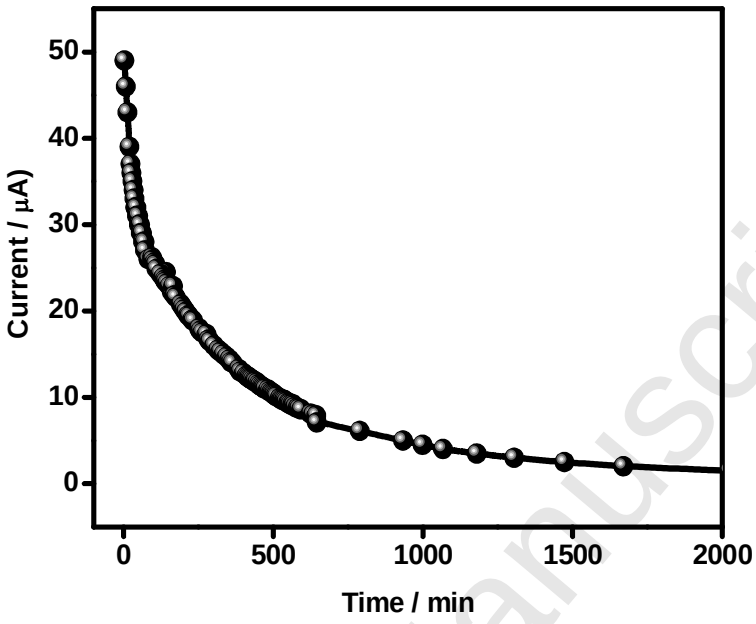


Figure 9 Leakage current curve of the all solid state capacitor comprising PAC (OCC) based polymer electrodes

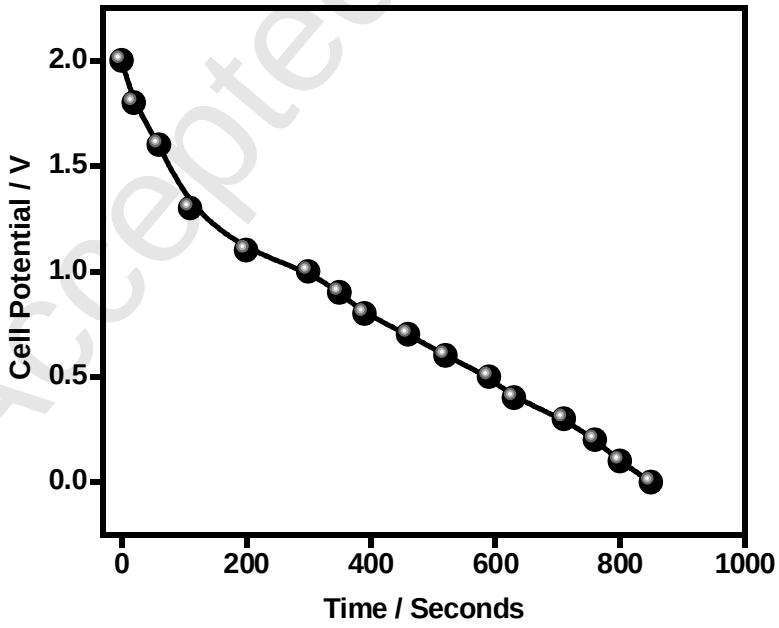


Figure 10 Self-discharge curves of the all solid state capacitor based on PAC (OCC) polymer electrode after charged at 2.0 V and left for 800 min.

Table 1 Equivalent circuit parameters deduced by fitting the impedance plots to the circuit of Figure 3.

Sample **1-x (70PEO:30AgI): x AC**	**R_s** (Ω) cm^2	**R_{ct}** (Ω) cm^2	**C_{dl}** mF cm^{-2}	**W** (Ω) cm^2 $s^{-1/2}$	**C_1** mF cm^{-2}	**R_f** (Ω) cm^2
X = 30 (wt.%)	10.7	23.1	5.2	6.1	2.3	0.2
X = 40 (wt.%)	38.3	53.2	4.4	5.1	0.8	0.4
X = 50 (wt.%)	55.5	72.3	3.1	4.9	0.2	0.5

Highlights

- New silver ion conducting solid polymer electrolyte based on activated carbon
- 70(70PEO:30AgI):30 AC exhibits the highest conductivity
- All solid state symmetric capacitor is reported.
- The presence of activated carbon mimics as capacitive behavior

Synthesis and Characterization of Solid Polymer Electrolyte based on Activated Carbon for Solid State Capacitor

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